surface ocean **solas** lower atmosphere study

Report for the year 2023 and future activities

SOLAS *France*
compiled by: Marie Boye, Karine Sellegri, Rémi Losno

This report has two parts:

***- Part 1:** reporting of activities in the period of January 2023 - Feb/Mar 2024*
***- Part 2:** reporting on planned activities for 2024 and 2025.*

The information provided will be used for reporting, fundraising, networking, strategic development and updating of the live web-based implementation plan. As much as possible, please indicate the specific SOLAS 2015-2025 Science Plan Themes addressed by each activity **or specify an overlap between Core Themes or Cross-Cutting Themes.**

Core Theme 1: Greenhouse gases and the oceans;
Core Theme 2: Air-sea interfaces and fluxes of mass and energy;
Core Theme 3: Atmospheric deposition and ocean biogeochemistry;
Core Theme 4: Interconnections between aerosols, clouds, and marine ecosystems;
Core Theme 5: Ocean biogeochemical control on atmospheric chemistry;
Cross-Cutting Theme: Integrated studies of high sensitivity systems (upwelling systems, Indian Ocean, polar oceans and sea ice);
Cross-Cutting Theme: Climate intervention;
Cross-Cutting Theme: Science and society**.**

First things first…Please tell us what the IPO may do to help you in your current and future SOLAS activities. ?

PART 1 - Activities from January 2023 to Feb/Mar 2024

1. Scientific highlight

C. Panagiotopoulos (christos.panagiotopoulos@mio.osupytheas.fr), K. Violaki, J. Castro-Jimenez, A. Nenes, R. Sempéré, Institut Méditerranéen d'Océanologie

Spatial and temporal patterns of organophosphate Esters flame retardants and plasticizers in airborne particles over the Mediterranean sea

Organophosphate esters flame retardants (OPEs) were measured in total suspended particles at the two edges of the Mediterranean Sea (semi-rural areas at Heraklion/Crete and Marseille/France) under the influence of the transport of polluted air from Europe and dust from the Sahara. In NW Mediterranean total average Σ_6OPEs concentration was 2103 ± 2020 pg m^{-3} (n = 23) with 2-ethylhexyl diphenyl phosphate (EHDPP) and tris(1-chloro-2-propyl) phosphate (TCPP) to be the predominant OPEs, accounting on average for 46% and 37% of the total Σ_6OPEs concentrations, respectively. On the other hand, the average concentration of Σ_6OPEs in East Mediterranean was 156.4 ± 170.3 pg m^{-3} (n = 67) with TCPP showing the highest concentration (116.1± 92.8 pg m^{-3}), followed by Tris-(2-chloroethyl) phosphate (TCEP) with an average concentration of 67.5 ± 55.8 pg m^{-3}. The highest concentrations were recorded during the summer period in the East Med. while in the NW Med. was recorded during spring. The latter is justified from the presence of EHDPP with higher concentrations during Saharan dust transportation, which happens more often in the spring. In both areas, OPEs were mostly associated with fossil fuel combustion and road traffic, while the air masses from Saharan desert influenced the concentration of EHDPP, TCEP in NW Mediterranean and the TCEP concentration levels in the East Mediterranean. The total concentration of OPEs in NW Med. was 57 times higher than the East area, while the total annual deposition of OPEs to the Mediterranean basin was estimated to 584 tonnes, accounting for about 8.5% of the total deposited anthropogenic phosphorus. The implications of the increased OPE-induced compounds of anthropogenic origin will likely affect the extremely low P pool in the Mediterranean Sea and therefore should be one of the research priorities in the future due do the massive global used of these plastic additives with the lack of a sound regulatory framework.

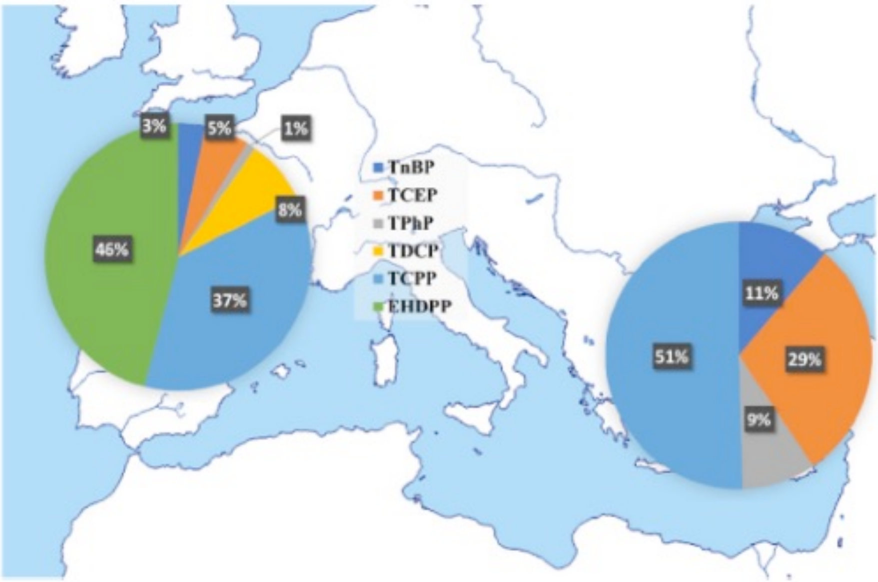

Figure 1. *Relative abundance of the main OPE's species detected in East and West Med. area*

Reference

Violaki et al. (2024). Chemosphere 348, 140746, DOI:10.1016/j.chemosphere.2023.140746

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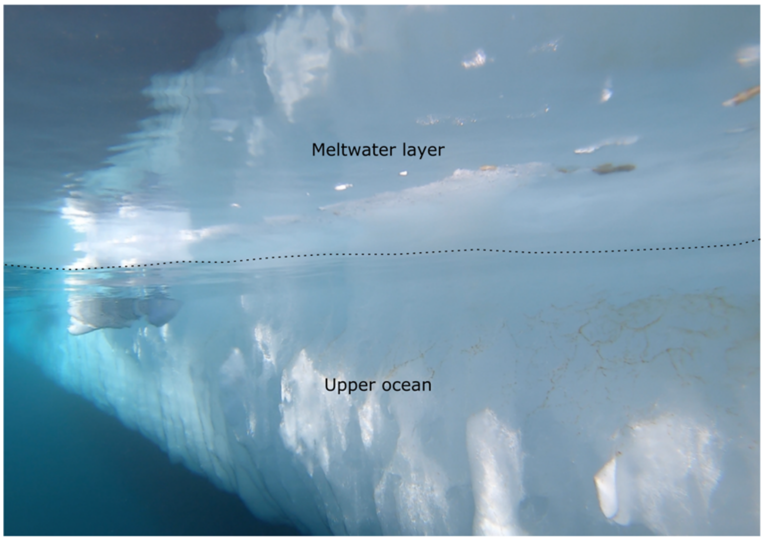
Multidisciplinary drifting Observatory for the Study of Arctic Climate

During Arctic summers, rapid snow and sea ice melt release low-salinity meltwater into the surface ocean, forming thin layers on and under sea ice floes (see Photos). Recent observations from the Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC) expedition highlight the persistence and impact of these meltwater layers, which act as barriers for nutrient and gas exchange, influencing ecosystem dynamics (Smith et al., 2023). Additionally, these layers affect atmospheric mercury (Hg) concentrations in the Arctic (Yue et al., 2023). Analysis from MOSAiC, coupled with modeling suggests that over 50% of the explained variability in atmospheric Hg concentrations is due to oceanic evasion. Notably, this process occurs predominantly in the Marginal Ice Zone rather than the central Arctic Ocean. These findings suggest that meltwater layers may contribute to the lack of Hg evasion from the central Arctic by buffering gas exchange processes. This underscores the complex relationship between Arctic sea ice changes and lower atmospheric composition.

North Pole (August 2020)
Photo : H. Angot

Surface stratification
Photo : M. Smith



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Smith, M.M., Angot, H., et al.: Thin and transient meltwater layers and false bottoms in the Arctic sea ice pack-Recent insights on these historically overlooked features, Elem. Sci. Anthr., 11, 00025, https://doi.org/10.1525/elementa.2023.00025, 2023.
Yue, F., Angot, H., et al.: The Marginal Ice Zone as a dominant source region of atmospheric mercury during central Arctic summertime, Nat. Commun., 14, 1–13, https://doi.org/10.1038/s41467-023-40660-9, 2023.

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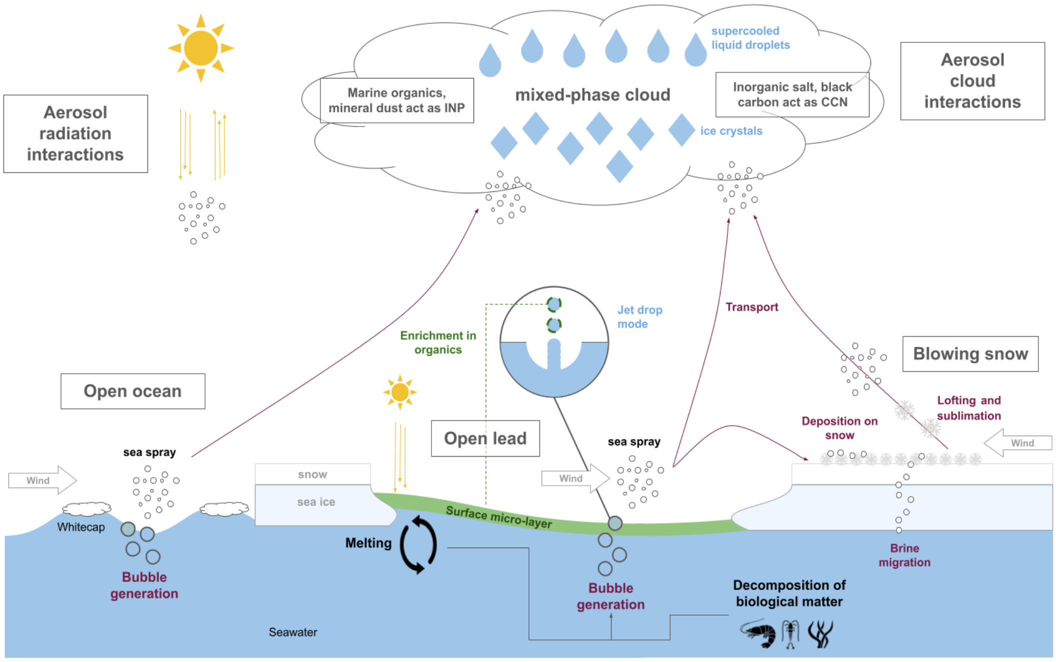
The Representation of Sea Salt Aerosols and Their Role in Polar Climate Within CMIP6

The ocean is a major source of aerosols and aerosol precursors. These aerosols then impact the climate through their interaction with sunlight (direct effect) and their role in cloud formation (indirect effect). We evaluated how sea salt aerosols are represented in polar regions in CMIP6 models and found a large diversity across models, and an inadequate representation of seasonality compared to observations at high latitudes (Lapere et al., 2023). The misrepresentation at high-latitude, which implies a large uncertainty on the radiative budget, can be attributed to the absence of representation of the sources of sea salt in sea ice regions (blowing snow, leads) in the CMIP6 climate models. This finding motivated the development of the first parameterization for the representation of sea spray fluxes emitted from leads (Lapere et al., in prep). Computations with a conceptual model and sensitivity analyses with the WRF-Chem regional atmospheric chemistry model indicate that sea salt aerosols from leads in the Arctic could be as important for the aerosol budget as the sea salt aerosols transported from open ocean regions. The ocean also releases gases such as DMS that can lead to the formation of secondary aerosols highly relevant for cloud formation. We are currently working with the University of Victoria on improving the oceanic DMS used as a boundary condition in WRF-Chem and the representation of its chemistry.



Schematic of the ocean-atmosphere interactions in polar regions through sea spray aerosols. Created by R. Lapere.

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Lapere, R., Thomas, J. L., Marelle, L., Ekman, A. M. L., Frey, M. M., Lund, M. T., et al. (2023). The representation of sea salt aerosols and their role in polar climate within CMIP6. Journal of Geophysical Research: Atmospheres, 128, e2022JD038235. doi.org/10.1029/2022JD038235

Lapere, R., Thomas, J. L., Marelle, L., et al. Bounding the contribution of leads to sea spray aerosol emissions in the high Arctic, in prep.

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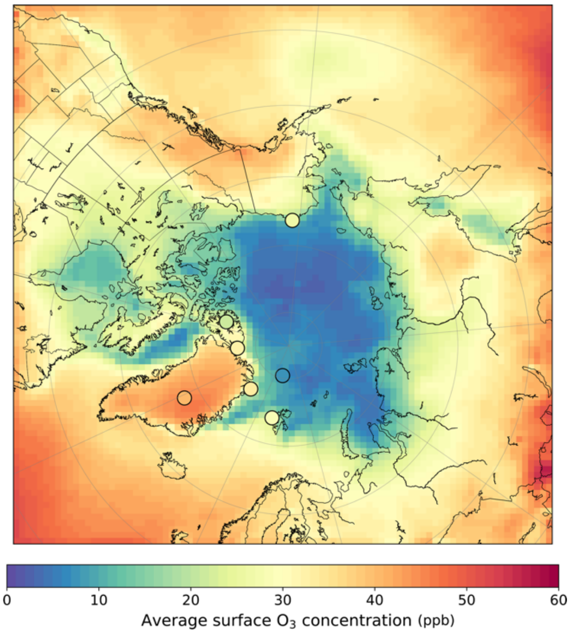
Coupled chemical cycling between sea-ice, snow, and the atmosphere during Arctic spring

Near-surface mercury and ozone depletion events occur in the lowest part of the atmosphere during Arctic spring. Mercury depletion is the first step in a process that transforms long-lived elemental mercury to more reactive forms within the Arctic that are deposited to the cryosphere, ocean, and other surfaces, which can ultimately get integrated into the Arctic food web. Depletion of both mercury and ozone occur due to the presence of reactive halogen radicals that are released from snow, ice, and aerosols. In this work, we added a detailed description of the Arctic atmospheric mercury cycle to our recently published version of the Weather Research and Forecasting model coupled with Chemistry (WRF-Chem 4.3.3) that includes Arctic bromine and chlorine chemistry and activation/recycling on snow and aerosols. The major advantage of our modelling approach is the online calculation of bromine concentrations and emission/recycling that is required to simulate the hourly and daily variability of Arctic mercury depletion. We used this model to study coupling between reactive cycling of mercury, ozone, and bromine during the Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC) spring season in 2020 and evaluated results compared to land-based, ship-based, and remote sensing observations. The model predicts that elemental mercury oxidation is driven largely by bromine chemistry and that particulate mercury is the major form of oxidized mercury. The model predicts that the majority (74%) of oxidized mercury deposited to land-based snow is re-emitted to the atmosphere as gaseous elemental mercury, while a minor fraction (4%) of oxidized mercury that is deposited to sea ice is re-emitted during spring. Our work demonstrates that hourly differences in bromine/ozone chemistry in the atmosphere must be considered to capture the springtime Arctic mercury cycle, including its integration into the cryosphere and ocean.



Simulated mean surface ozone concentration. *Surface ozone concentration is averaged for the full simulation period (March 14 to April 14, 2020). Observational averages for the same period are shown by markers with the same colour scale.*

Reference

Shaddy, A., Thomas, J.L., et al.: Modelling the coupled mercury-halogen-ozone cycle in the central Arctic during spring, *Science of the Anthropocene*, 11 (1): 00129, 2023. doi.org/10.1525/elementa.2022.00129

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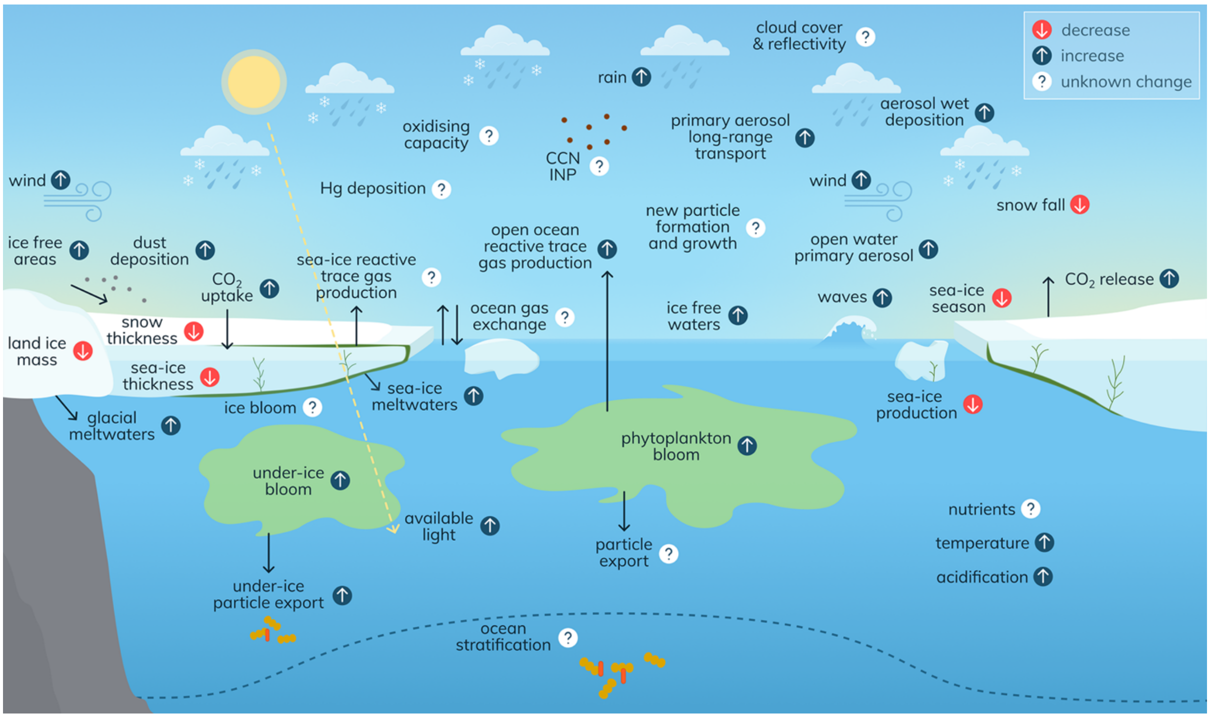
Polar oceans and sea ice in a changing climate

Polar oceans and sea ice cover 15% of the Earth's ocean surface, and the environment is changing rapidly at both poles. Improving knowledge on the interactions between the atmospheric and oceanic realms in the polar regions, a Surface Ocean-Lower Atmosphere Study (SOLAS) project key focus, is essential to understanding the Earth system in the context of climate change. However, our ability to monitor the pace and magnitude of changes in the polar regions and evaluate their impacts for the rest of the globe is limited by both remoteness and sea-ice coverage. Sea ice not only supports biological activity and mediates gas and aerosol exchange but can also hinder some in-situ and remote sensing observations. While satellite remote sensing provides the baseline climate record for sea-ice properties and extent, these techniques cannot provide key variables within and below sea ice. Recent robotics, modeling, and *in-situ* measurement advances have opened new possibilities for understanding the ocean–sea ice–atmosphere system, but critical knowledge gaps remain. Seasonal and long-term observations are clearly lacking across all variables and phases. Observational and modeling efforts across the sea-ice, ocean, and atmospheric domains must be better linked to achieve a system-level understanding of polar ocean and sea-ice environments. As polar oceans are warming and sea ice is becoming thinner and more ephemeral than before, dramatic changes over a suite of physicochemical and biogeochemical processes are expected, if not already underway. These changes in sea-ice and ocean conditions will affect atmospheric processes by modifying the production of aerosols, aerosol precursors, reactive halogens and oxidants, and the exchange of greenhouse gases. Quantifying which processes will be enhanced or reduced by climate change calls for tailored monitoring programs for high-latitude ocean environments. Open questions in this coupled system will be best resolved by leveraging ongoing international and multidisciplinary programs, such as efforts led by SOLAS, to link research across the ocean-sea ice-atmosphere interface.



Climate change impacts on key environmental conditions and processes in polar oceans and sea ice (Willis et al., 2023)

Reference
Willis, M.D., et al., 2023. Polar oceans and sea ice in a changing climate. Elementa: Science of the Anthropocene 11(1). DOI: https://doi.org/10.1525/elementa.2023.00056

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Tropical island mass-effect on coastal biogeochemistry and phytoplankton assemblage: the case of Guadeloupe (French West Indies)

Tropical islands are often located in oligotrophic gyres, where nitrogen is the most limiting macronutrient for phytoplankton development. Those oceanic provinces can also be co-limited by low inputs of nutritive metals such as iron. However, phytoplankton production can be very intense around islands, as shown by satellite observations. It is due to the various inputs originating from the island (rivers, runoff water, groundwater) and to processes occurring around it (upwelling, vertical mixing, resuspension of sediment, atmospheric Saharan dust deposition, wet deposition) as represented in the Guadeloupe island where no study is existing (Fig. 1). Topography and exposition to the wind also play a major role in the nutrient distribution. In order to quantify these inputs and determine the impact on the phytoplankton assemblage, we did two field campaign at sea and on land in Basse-Terre (Guadeloupe) during the wet season (June 2023) and dry season (January 2024) to capture the seasonality effect.

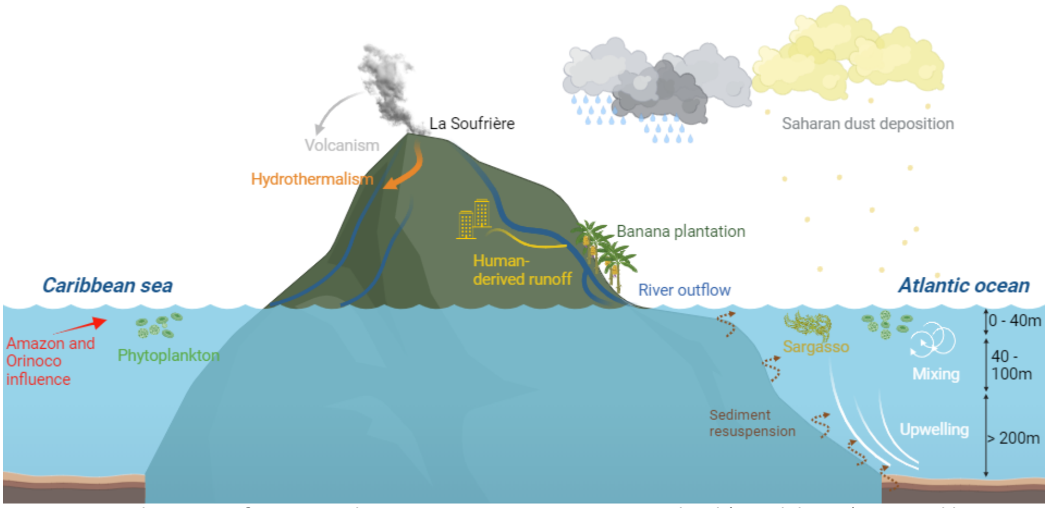

Figure 1: *Potential sources of macro and micro-nutrients in Basse-Terre island (Guadeloupe). Created by E. Moreau.*

Preliminary results obtained during the wet season suggested that the island mass effect is different depending on the coast and it is not exported offshore. Indeed, on the Atlantic coast, atmospheric dust deposition and rivers (weathering) are sources of particulate iron and the coastal sediment dissolution is a major source of dissolved iron. Human activities are a major source of nitrate. These high nutrient concentrations explain the relatively high chlorophyll-a concentration and the dominance of diatoms on the shelf. By contrast, on the Caribbean coast, dissolved iron is coming from hydrothermal activity but there are low nitrate concentrations corresponding to oligotrophic waters. This amount of nutrients can explain a much lower chlorophyll-a concentration and the predominance of cyanobacteria (Moreau et al., *in prep*.).

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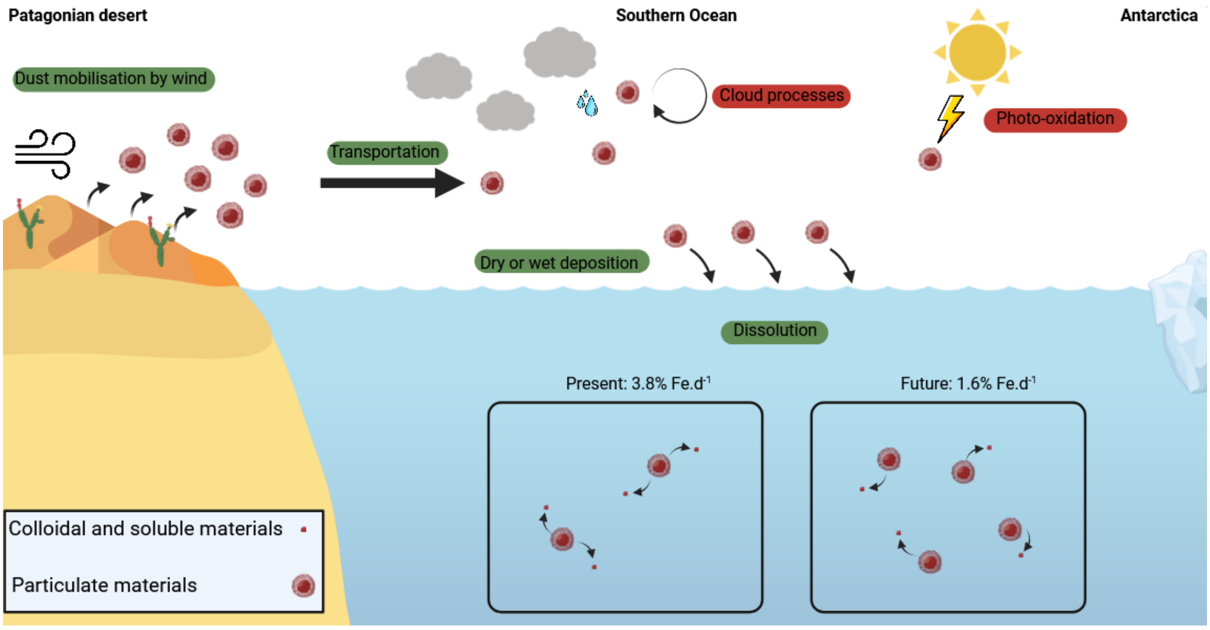
Clément Demasy (demasy@sun.ac.za) and Marie Boye (boye@ipgp.fr)

Highlight 1- Iron dissolution from Patagonian dust in the Southern Ocean: under present and future conditions

Although the input of desert dust as a key source of trace metals in the Southern Ocean (SO) has been previously studied, the dissolution process of metals in surface waters, particularly iron (Fe), remain poorly understood. Given the crucial role of Fe in primary production and the biological carbon pump in the SO, we focused on experimental estimations of Fe dissolution from Patagonian dust, the primary natural dust source in the SO. There, we aimed to diagnose the effects of increased dust deposition and other predicted changes on the solubility of Fe and other trace metals in Patagonian dust. Our study considered both current and projected future conditions, encompassing sea-surface warming, acidification, increased photosynthetically active radiation, and doubled dust inputs. Through controlled laboratory experiments using filtered SO seawater, conducted over 7 days, we assessed changes in particulate Fe (pFe) concentrations, Fe redox speciation (Fe(II)/Fe(III)), and in the mineralogy of Fe-bearing dust in abiotic condition.
The predominant minerals in the dust included quartz and aluminosilicates, with silicon (Si), aluminum (Al), and Fe as the major elements. No significant alterations in the mineralogy and the elemental composition of the dust were recorded during the dissolution experiments, neither under present nor

under projected future conditions. The particulate Fe(II)/Fe(III) ratio remained consistently at 0.25 during the experiments, unaffected by changed conditions. Consequently, changes in environmental conditions in the SO would therefore not significantly alter the mineralogy and redox speciation of pFe in the Patagonian dust. On the contrary, pFe exhibited a dissolution rate of 3.8% and 1.6% per day under present and future conditions, respectively. The environmental changes anticipated for 2100 in the SO will likely result in a decrease in the dissolution rate of pFe. Consequently, the future intensification of Patagonian dust inputs may not alleviate the Fe limitation in the SO (Demasy et al., in press).



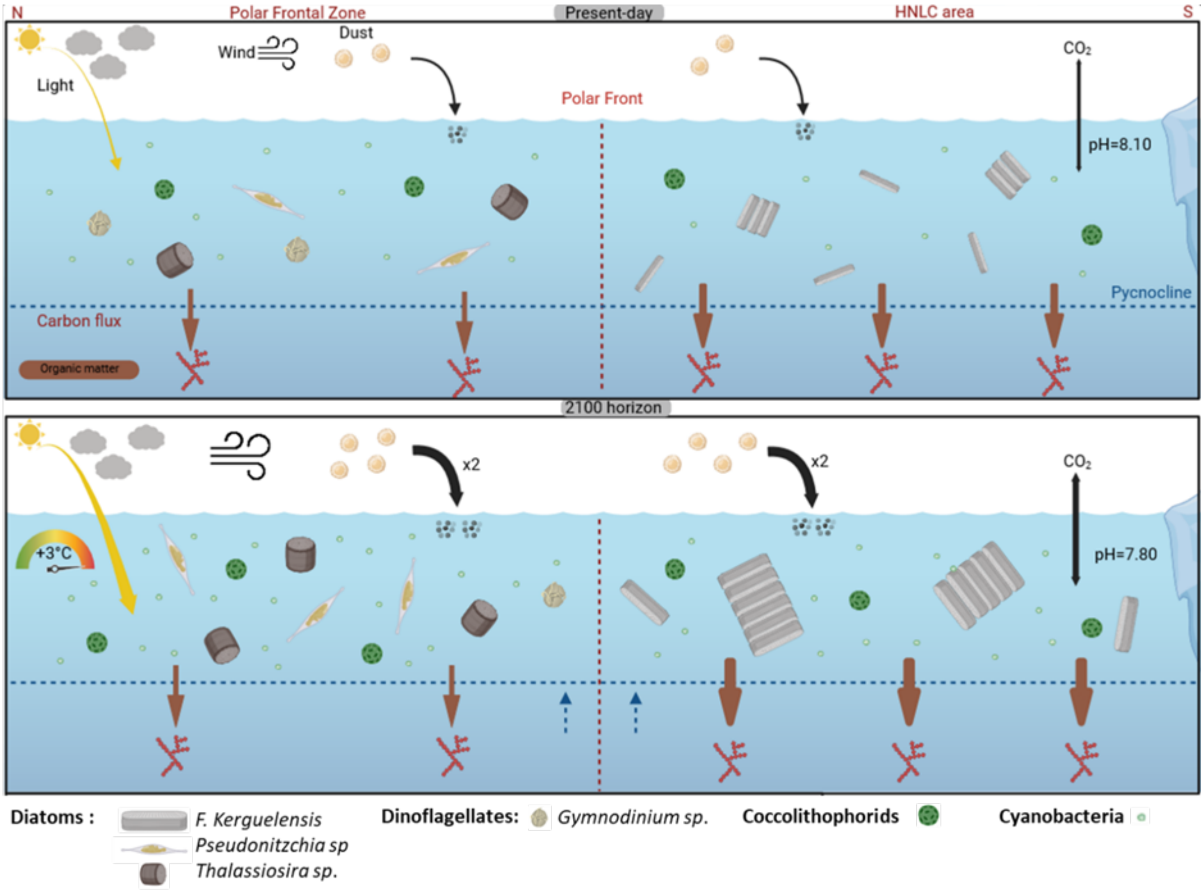
Conceptual scheme of Patagonian dust dissolution under present and future Southern Ocean conditions (Demasy et al., in press).

Highlight 2- Impact of Patagonian dust and future environmental changes on the natural phytoplankton community in the Polar Frontal Zone and the HNLC area of the Southern Ocean (Indian sector)

The Southern Ocean (SO) plays a major role in the global sequestration of atmospheric carbon dioxide, driven by its biological carbon pump. Atmospheric inputs from Patagonia are dominant in the SO and contribute to fertilize surface waters by providing iron and other nutrients to phytoplankton. Projections suggest an increase in these inputs alongside other anticipated environmental shifts like warming and acidification of waters by 2100. Yet, the cumulative effects of these changes and the intensification of Patagonian inputs on phytoplankton dynamics remain uncertain, potentially reshaping the intensity of the primary production.

We aimed to diagnose the net effect of these multifaceted changes on phytoplankton communities, assessing their individual and interactive effects. This study aimed to estimate the impacts of these changes on the growth, composition and productivity of phytoplankton assemblages in the Polar Frontal Zone (PFZ) and the HNLC region of the Indian sector of the SO during the austral 2022 summer aboard *R/V Marion Dufresne*. Natural phytoplankton communities underwent a 5-day incubation under 4 scenarios (actual and future environmental conditions, alongside 2 intermediate scenarios).

In the PFZ, warming and acidification stimulated phytoplankton growth, mainly cyanobacteria, while intensified dust inputs alone didn't exhibit significant impacts. Conversely, in HNLC waters, the addition of Fe-dust increased the biomass of diatoms (mainly *F. kerguelensis*) under current temperature and pH conditions, whereas the negative effect of acidification and warming in the future conditions counteracted the positive impact of Fe-dust input on the diatoms. The phytoplankton assemblage was not modified by future conditions in the PFZ and the HNLC area, where, respectively, picophytoplankton remained the predominant species at this season and diatoms persisted as the dominant biomass. The particulate organic carbon production by photosynthesis was also not altered by future conditions, suggesting that primary production may not change in the future SO. But the increase in the length and the number of long-chain diatoms under future conditions in the HNLC area may indicate that particulate organic carbon export may intensify in the future (Demasy et al., in prep.).



Conceptual schematic illustrating anticipated global change and the interactive effects of dust input on phytoplankton from two Southern Ocean regions. This visual was generated using BioRender website. Created by C. Demasy.

References

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Demasy, C. Boye, M., et al.: Responses of phytoplankton to Patagonian dust input and anthropogenic changes in the future Southern Ocean, *in prep.*

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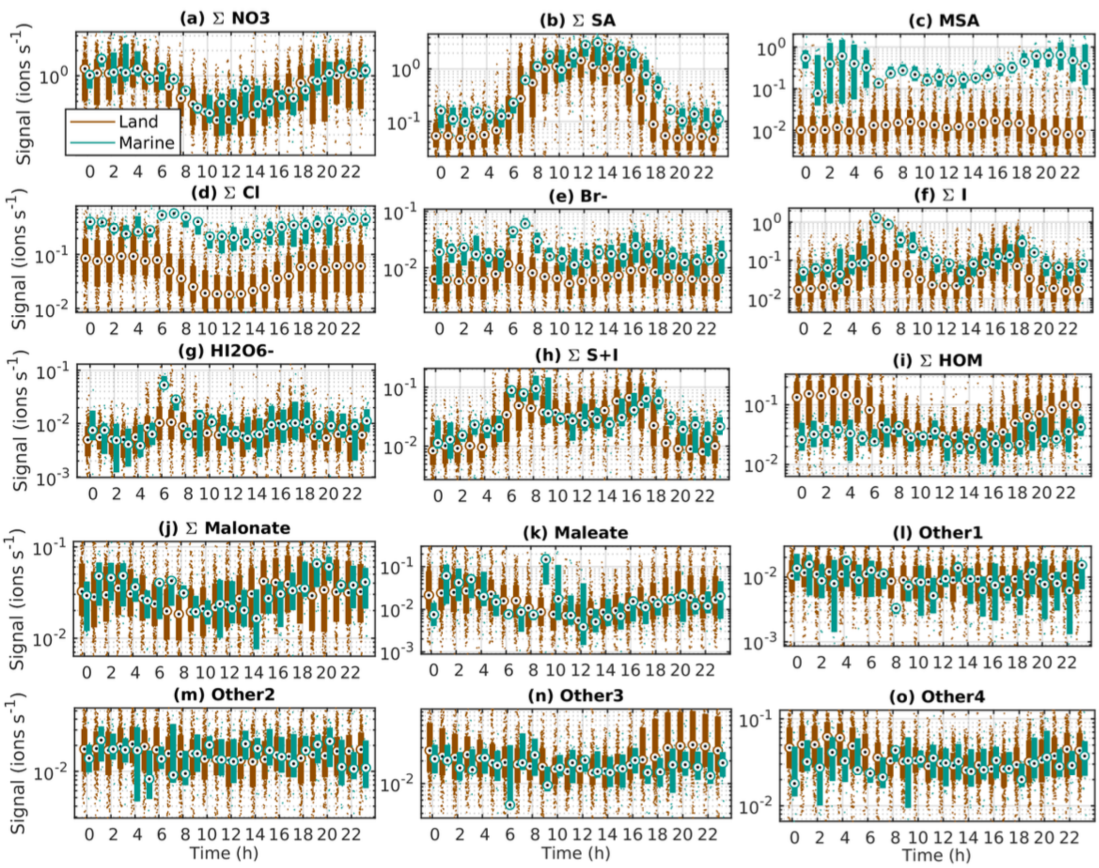
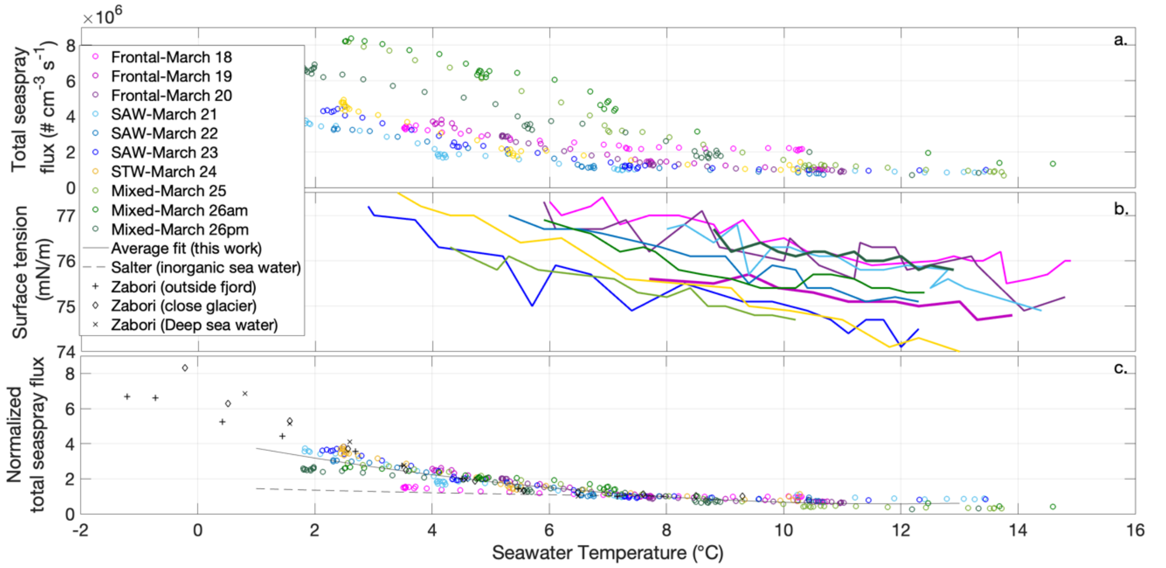
K. Sellegri (K.Sellegri@opgc.univ-bpclermont.fr) and co-workers, LaMP

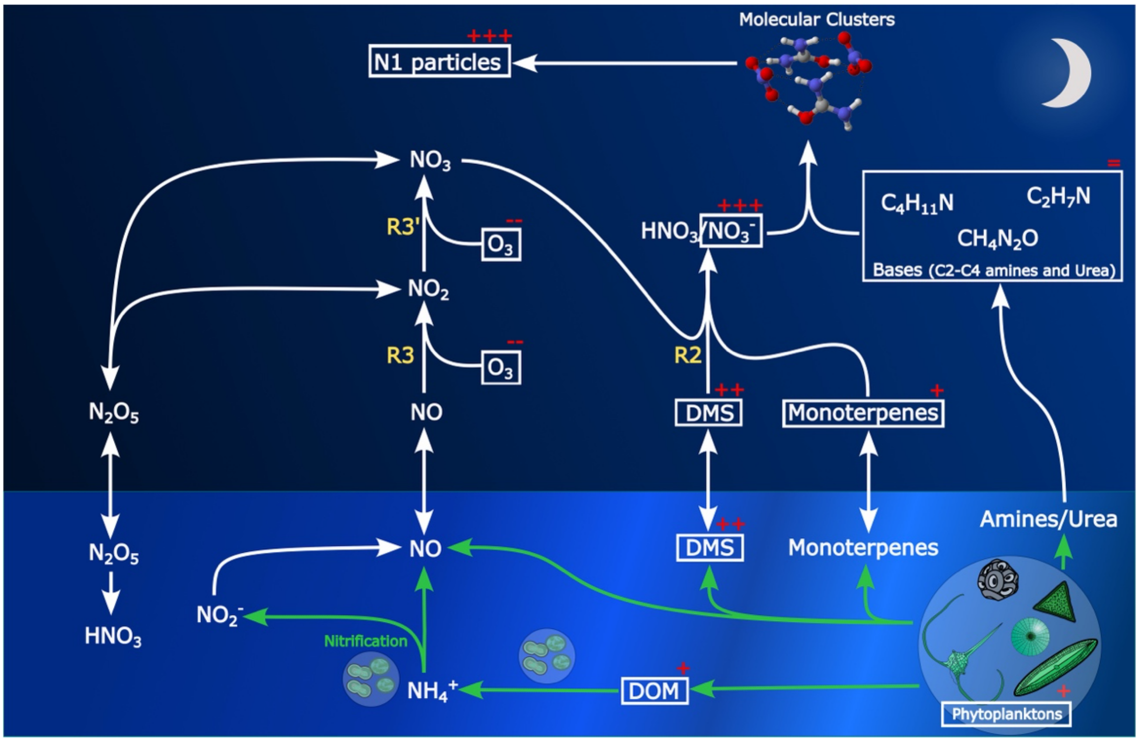
Highlight 1 (*Theme 5).* In Peltola et al. (2023), we report on the chemical precursors to nucleation in air masses originating from the open South Western Pacific Ocean. Measurements of natural ion clusters composition were conducted over 7 months at Baring Head, coastal New Zealand and showed that while over land new particle formation is likely driven by sulfuric acid and organic species, in clean marine air of this area iodine oxoacids and sulfur species are likely important drivers of particle formation processes. Bisulfate anions displayed a clear daytime maximum whereas iodine oxoacids had morning and evening maxima.



Highlight 2 (*Themes 4*). A french contribution to the international effort to gather the state of knowledge on aerosol-cloud interactions in the Southern Ocean. In Sellegri et al. (2023), we investigate the influence of surface seawater biogeochemical composition on the temperature dependence of number-based sea spray emission fluxes. The dependence of sea spray fluxes was investigated in different water masses (i.e., subantarctic, subtropical and frontal bloom) with contrasting biogeochemical properties across a temperature range from ambient (13-18°C) to 2°C using seawater circulating in a plunging jet sea spray generator. Sea spray total concentration was found to increase by an average 4-fold at 2°C compared to ambient temperatures, with the highest impact of temeprature in subtropical seawaters. The temperature dependence of the sea spray flux was found to be inversely proportional to the abundance of the cyanobacterium *Synechococcus* in seawater.



Highlight 3 (*Theme 5*). Using measurements collected in ship-borne air-sea interface tanks deployed in the Southwestern Pacific Ocean, Chamba et al. (2023) identified new particle formation during nighttime that was related to plankton community composition. They show that nitrate ions are the only species for which abundance could support new particle formation rates in the semi-controlled experiments. Nitrate ions also prevailed in the natural pristine marine atmosphere and were elevated under higher sub-10 nm particle concentrations. The hypothesis for the nitrate-based emissions that are complex, short-term biogeochemical cycling involving the microbial loop.



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Peltola, M., et al.: Chemical precursors of new particle formation in coastal New Zealand, Atmos. Chem. Phys., 23, 3955–3983, https://doi.org/10.5194/acp-23-3955-2023, 2023

Mallet M.D., et al.: Untangling the influence of Antarctic and Southern Ocean life on clouds, Elementa: Science of the Anthropocene (2023) 11 (1): 00130.https://doi.org/10.1525/elementa.2022.00130, 2023.
Sellegri, K., et al.: Quantified effect of seawater biogeochemistry on the temperature dependence of sea spray aerosol fluxes Atmos. Chem. Phys., https://doi.org/10.5194/acp-2022-790, 2023
Chamba G., et al.: Nitrate-based nighttime atmospheric nucleation driven by marine microorganisms, PNAS, 120 (48), https://doi.org/10.1073/pnas.2308696120, 2023.

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Research work over the last year has been carried out under the SOLAS cross-cutting theme Integrated topics: **Upwelling systems,** looking at **the impact of multi-stressors (warming, ocean acidification, deoxygenation) on marine ecosystems.**

Highlight 1. Major coastal upwelling systems are among the most productive marine ecosystems in the world. They contribute disproportionately to the cycling of carbon and nutrients in the ocean and influence marine biogeochemistry beyond their productive regions. Characterized by intense microbial respiration (both aerobic and anaerobic), major coastal upwelling systems are also hotspots for the production and outgassing of potent greenhouse gases (GHG) such as CO_2, N_2O, and CH_4. Quantifying and understanding these roles in the context of a changing climate is therefore a subject of great interest. Here we provide a short synthesis of the current knowledge of the contributions of major coastal upwelling systems to the cycling of GHG. Despite variations within and among different systems, low-latitude coastal upwelling systems typically act as a net carbon source to the atmosphere, while those at higher latitudes function as weak sinks or remain neutral regarding atmospheric CO_2. These systems also significantly contribute to oceanic N_2O and CH_4 emissions, although the extent of their contribution to the latter remains poorly constrained. We also overview recent and future changes to upwelling systems in the context of a warmer climate and discuss uncertainties and implications for GHG production. Although rapid coastal warming is anticipated in all major coastal upwelling systems, the future changes in upwelling-favorable winds and their implications within the context of increased stratification are uncertain. Finally, we examine the major challenges that impede our ability to accurately predict how major coastal upwelling systems will respond to future climate change, and present recommendations for future research to better capture ongoing changes and disentangle natural and forced variability.

*Overview of physical and biogeochemical processes in major coastal upwelling systems (Zouhair et al., 2024)***.**

Highlight 2. On-going climate change is now recognized to yield physiological stresses on marine species, with potentially detrimental effects on ecosystems. Here, we evaluate the prospect of using climate velocities (CV) of the metabolic index (Φ) for assessing changes in habitat in the South East Pacific. Methods: Our approach is based on a species with mean ecophysiotype (i.e. model species) and the use of a global Earth System Model simulation (CESM- LE) under RCP 8.5 scenario. The SEP is chosen as a case study as it hosts an Oxygen Minimum Zone and seamounts systems sustaining local communities through artisanal fisheries. Our results indicate that CV_Φ pattern is mainly constrained by the oxygen distribution and that its sign is affected by contrasting oxygen trends (including a re-oxygenation in the upper OMZ) and warming. We further show that CV_Φ is weakly dependent on physiological traits composing Φ, which conveys to this metrics some value for inferring the projected mean displacement and potential changes in viability of metabolic habitat in a region where physiological data are scarce. Based on sensitivity experiments to physiological traits and natural variability, we propose a general method for inferring broad areas of climate change exposure regardless of species-specific Φ. We show in particular that for the model used here, the upper OMZ region can be considered a "safe" area for the species with ecophysiotype close to that of 71 species used to derive the model species. Limitations of the approach and perspectives of this work are also discussed.

Highlight 3. The South East Pacific (SEP) is characterized by the presence of an oxygen minimum zone (OMZ) embedded in the subsurface waters of the very productive upwelling system along the coast of Peru and Chile. This OMZ is currently diversely simulated by state-of-the-art Earth System Models (ESM) hampering a reliable projection of ocean deoxygenation on marine ecosystem services in these regions. We showed that, despite the low consensus among ESM long-term projections of oxygen levels, the sensitivity of the depth of the upper margin (oxycline) of the SEP OMZ to El Niño events in an ensemble of ESMs can be used as a predictor of its long-term trend, which establishes an emergent constraint for the SEP OMZ. Because the oxycline along the coast of Peru and Chile deepens during El Niño events, the upper bound of the SEP OMZ is thus likely to deepen in the future climate, therefore oxygenating the SEP OMZ.

Highlight 4. While mechanisms are being established to strengthen ocean mitigation and adaptation measures across relevant UN and international conventions, capacity for generating tailored information for local management, policy response and preparedness remains a significant barrier to advancing necessary adaptation efforts to help break down this barrier, OARS Outcome 3 will contribute to co-design and implement observation strategies in collaboration with data/information producers and end-users, supported by capacity building, to ensure vulnerable areas are adequately monitored and baseline information for newly developed carbon removal strategies is provided. To have the capability to effectively co-design activities, all interested stakeholders involved in that co-building of observing systems need an effective knowledge to engage more effectively. Stakeholders need to understand how the natural and human systems work and how they interact. Without this key understanding, there will not be any willingness for action. We witness a current plethora of individual monitoring activities operating over different spatial and temporal scales, all with different objectives and approaches. Only targeted co-built observation strategies will guide successful coral reef restoration, fisheries and aquaculture resilience strategies, innovative nature- based projects, carbon removal strategies, land-based pollution controls and climate responsive marine spatial planning and conservation effort.

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Parouffe A, et al., 2023, Evaluating future climate change exposure of marine habitat in the South East Pacific based on metabolic constraints. *Front. Mar. Sci*. 9:1055875. doi: 10.3389/fmars.2022.1055875

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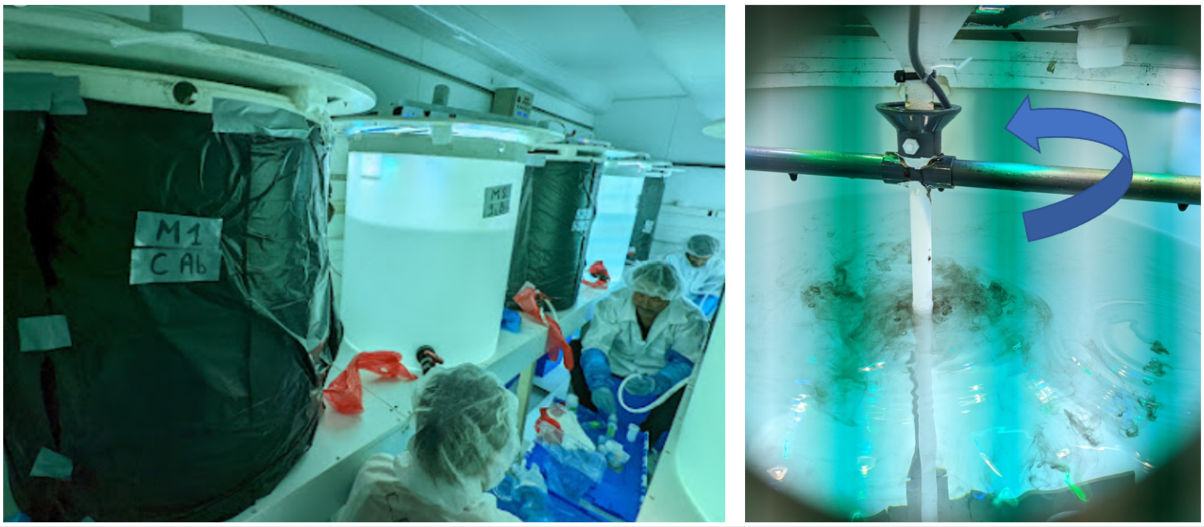
C. Guieu (cecile.guieu@imev-mer.fr), LOV, and E. Ortega-Retuerta (eva.ortega-retuerta@obs-banyuls.fr), LOMIC

How biomass combustion aerosols affect the chemical composition of seawater and what is its impact on marine micro-organisms?

The overall aim of PYROPLANKTON (PI J. Llort, funded by ESA) and PYROPLANKTON-LEFE (PIs C. Guieu, LOV et E. Ortega-Retuerta LOMIC, funded by LEFE of French CNRS-INSU in 2023-2024) is to provide a detailed mechanical understanding of how biomass combustion aerosols affect the chemical composition of seawater and its impact on marine micro-organisms. A combination of experimental approach (know-how at LOV) and modeling of the parameters obtained (know-how of Joan Llort, Computer Center, Barcelona), will enable us to better represent this source of nutrients for the water column. In July 2022, for the first time at LOV, we conducted a ground-breaking experiment using ash collected after a real forest fire (collaboration Cristina Santin, Spain), to gain a detailed mechanical understanding of how biomass combustion aerosols (BBa) disrupt the chemical composition of seawater and their impact on marine micro-organisms. To do this, we used our cleanroom container in "sedentary" mode in the laboratory, pumping water from the Bay of Villefranche during the oligotrophic summer season. These experiments enabled us to quantify, for the 1st time, the adsorption/desorption kinetics of nutrients and metals (with a strong focus on iron) provided by BBa in seawater, the pattern of dissolved organic matter, as well as their impact on biota (bacteria and phytoplankton). Results have been presented at several occasion by C. Guieu (XMAS-VI 2023) and J. Llort (ASLO Aquatic Sciences Meeting 2023) and are currently under publication.



The experiment lasted 14 days. Among the 9 tanks: 4 were filled with 0.2 µm filtered seawater to remove phytoplankton (1 control with no addition and 3 with the same atmospheric flux) (those tanks are covered with black plastic bags on the left picture); 5 tanks were filled with unfiltered seawater (=natural assemblage) (1 control with no addition and 5 tanks representing a gradient of atmospheric deposition). We chose to represent wet deposition and designed a rotating device that correctly imitated the rain droplets containing the BBa particles deposited on the surface of each tank.

Reference

Guieu C., et al.: Biogeochemical response in surface ocean after wildfire ash deposition: results from minicosms experiment. Sixth Xiamen Symposium on Marine Environmental Sciences (XMAS-VI), Jan 9-12, 2023 (EST Time) in Xiamen, China. Invited Speech

Llort J., et al.: Biogeochemical impacts of wildfire ash deposition on the surface ocean: results from minicosms experiment, ASLO Aquatic Sciences Meeting 2023, 4-9 June 2023 · Palma de Mallorca, Spain

2. Activities/main accomplishments in 2023 (e.g., projects; field campaigns; workshops and conferences; model and data intercomparisons; capacity building; international collaborations; contributions to int. assessments such as IPCC; collaborations with social sciences, humanities, medicine, economics and/or arts; interactions with policy makers, companies, and/or journalists and media).

<u>POLAR-Change</u>

The POLAR-CHANGE ship campaign, led by the Institut de Ciences del Mar in Barcelona, took place on board on the Hesperides, in the Weddell Sea (Antarctica) during Feb-March 2023 with the goal of investigating how sea ice melting is impacting primary and secondary marine emissions. CNRS-LaMP contributed to this ship campaign with shipborne mesocosms for characterizing gaz-phase precursors to nucleation and with temperature-controlled sea spray generation.

<u>CRiceS</u>

Climate Relevant interactions and feedbacks: the key role of sea ice and Snow in the polar and global climate system (https://www.crices-h2020.eu/).

The Arctic and Antarctic regions are experiencing rapid and unprecedented changes due to polar and global climate change, clearly caused by anthropogenic activities. 21st century projections show substantial decrease of sea ice in both Arctic and Antarctic, which are expected to impact people in the Arctic and also society beyond polar regions. The CRiceS project focuses on improving model predictions of the role of polar processes in the climate system that consists of the oceans, ice and

snow cover, and the atmosphere. It is crucial to understand the role of the polar processes, such as feedback loops, in polar and global climate. One of the main ways scientists can improve our understanding of environmental change is to combine knowledge from different disciplines in a coordinated way. The CRiceS project brings together 20 international research teams, from Europe, Canada, South Africa, and India, at the forefront of polar and global climate research. The CRiceS research project aims to enhance the modelling of the impacts that these regions have for the global climate.
Policy brief from projects CRiceS and PolarRES : Enhancing Polar System Representation in Models for EU Climate Decision-Making (https://www.crices-h2020.eu/news/enhancing-polar-system-representation-in-models-for-eu-climate-decision).

CERTAINTY

Cloud-aERosol inTeractions & their impActs IN The earth sYstem (https://certainty-aci.eu/).
The recent decade has seen an unprecedented acceleration in climate change and related weather extremes. Significant questions remain regarding how aerosol-cloud-radiation interactions control and modify these events. CERTAINTY aims to deliver the knowledge and models that provide improved confidence and representation of the role of cloud-aerosol-radiation interactions in climate and weather. This translates to better understanding and predictions of extreme events and facilitates planning climate mitigation and adaptation strategies for the good of the society.

ISLE

The project ISLE aimed to evaluate the island mass-effect on marine biogeochemistry and the phytoplankton assemblage in the tropical island of Guadeloupe (French West Indies). Two field campaigns at sea and on land were carried out by an IPGP team in collaboration with the University of Antilles (Pierre-Yves Pascal) and ObsERA (Observatory of Water and Erosion in the Antilles, Céline Dessert, IPGP) in June 2023 and January 2024 to examine this island mass-effect.

Selected communications at International Conferences

Boye M., Demasy C., Delisée A., Moreau E., Burckel P., Maguer J-F., L'Helguen S., Leblanc K., Thyssen M., Losno R.: Responses of phytoplankton to Patagonian dust input and anthropogenic changes in the future Southern Ocean. SOLAS Open Science Conference, September 2022, Cape Town, South Africa.

Boye M., Demasy C., Moreau E., Delisée A., Losno R., Burckel P., Maguer J-F., Leblanc K., Thyssen M.: Responses of phytoplankton to Patagonian dust input and anthropogenic changes in the future Southern Ocean. Ocean Sciences Meeting, 18-23 Feb 2024, New Orleans, La., USA.

Demasy C., Boye M., Burckel P., Monna F., Losno R.: Solubility of trace metals from Patagonian dust in the future Southern Ocean. Oral presentation, AGU Fall Meeting, 16/12/2021, New Orleans, visioconference.

Demasy C., Boye M., Burckel P., Monna F., Losno R.: Solubility of trace metals from Patagonian dust in the future Southern Ocean. Oral presentation, SOLAS France meeting, 29/03/2021, visioconference.

Demasy C., Boye M., Lai B., Burckel P., Feng Y., Losno R., Borensztajn S., Besson P.: Iron dissolution from Patagonian dust in the Southern Ocean: under present and future conditions. 27/03/2024, Department of Earth Sciences, Stellenbosch University, Stellenbosch, South Africa.

Demasy C.: Solubility and bioavailability of Patagonian dust in the future Southern Ocean. 16/03/2023, Laboratoire des sciences du climat et de l'environnement, Gif sur Yvette, France.

Galí, M., del Valle, D.A., Archer, S.D., Bange, H.W., Bucciarelli, E., Deschaseaux, E.S.M., González, J.M., Hayashida, H., Hopkins, F.E., Kameyama, S., McParland, E.L., Park, K.T., Shenoy, D., Stefels, J., Todd, J.D., Tortell, P.D., Winkel, L.H.E., Yang, G.-P., Zárate, M., Zhang, M., 2023. Establishing an international, multidisciplinary community of practice for the study of methylated sulfur compounds in the ocean: SCOR working group DMS-PRO. *ASLO Aquatic Sciences meeting*, June 4-9, Palmas de Mallorca, Spain.

Guieu C., Llort J, Bressac M, Gazeau F, Urruti P, Montanes M, Uher E, Santin C, Santiso M, Djaoudi K, Pulido E, Ortega-Retuerta E, Marie B, Biogeochemical response in surface ocean after wildfire ash deposition: results from minicosms experiment. Sixth Xiamen Symposium on Marine Environmental Sciences (XMAS-VI), Jan 9-12, 2023 (EST Time) in Xiamen, China. *Invited Speech*

Hayashida, H., Galí, M., del Valle, D.A., Archer, S.D., Bange, H.W., Bucciarelli, E., Deschaseaux, E.S.M., González, J.M., Hayashida, H., Hopkins, F.E., Kameyama, S., McParland, E.L., Park, K.T., Shenoy, D., Stefels, J., Todd, J.D., Tortell, P.D., Winkel, L.H.E., Yang, G.-P., Zárate, M., Zhang, M., Ishino, S., Angot, H., Haddon, A., Joge, S., Lim, H.-G., Mahajan, A., Peeken, I., Steiner, N., Thomas, J., Willis, M., 2023. Sulfur Cycle Research Activities within SCOR Working Groups DMS-PRO and CIce2Clouds. *Asia Oceania Geosciences Society conference*, July 30-Aug. 4, Singapore.

Llort J., Guieu C., Bressac M, Gazeau F, Urruti P, Montanes M, Uher E, Santin C, Santiso M, Djaoudi K, Pulido E, Ortega-Retuerta E, Marie B, Biogeochemical impacts of wildfire ash deposition on the surface ocean: results from minicosms experiment, ASLO Aquatic Sciences Meeting 2023, 4-9 June 2023 · Palma de Mallorca, Spain.

Moreau E., Boye M., Pascal P.Y., Dessert C., Losno R., Messié M., Burckel P. (2023). Tropical Island Mass Effect on Coastal Biogeochemistry and Phytoplankton Assemblages: The Case of Guadeloupe (French West Indies). AGU, 11-15 Dec 2023, San Francisco, USA.

Moreau E., Boye M., Pascal P.Y., Dessert C., Losno R., Messié M., Burckel P. (2024). Tropical Island Mass Effect on Coastal Biogeochemistry and Phytoplankton Assemblages: The Case of Guadeloupe (French West Indies). Ocean Sciences Meeting, 18-23 Feb 2024, New Orleans, LA., USA.

3. Publications in 2023 (only PUBLISHED articles) and if any, weblinks to models, datasets, products, etc.

Contributions of French community to international collaborative works:

Mallet M. D., R. S. Humphries, S. L. Fiddes, S. P. A., K. Altieri, H. Angot, N. Anilkumar, T. Bartels-Rausch, J. Creamean, M. Dall'Osto, A. Dommergue, M. Frey, S. Henning, D. Lannuzel, R. Lapere, G. G. Mace, Anoop S. Mahajan, Greg M. McFarquhar, Klaus M. Meiners, B. Miljevic, I. Peeken, A. Protat, J. Schmale, N. Steiner, K. Sellegri, R. Simó, J. L. Thomas, M. D. Willis, V. Holly L. Winton, M. T. Woodhouse, Untangling the influence of Antarctic and Southern Ocean life on clouds, Elementa: Science of the Anthropocene (2023) 11 (1): 00130.https://doi.org/10.1525/elementa.2022.00130, 2023.

Garçon, V., Hernandez Ayon, J., Dupont, S., Isensee, K., Currie, K., Widdicombe, S., Telszewski, M., Newton, J., Valauri-Orton, A., Feely, R., Turner, J., Seeyave, S., Dickson A., Venus, M., Hales, B., Kitch, G., Grabb, K., 2024. OARS Outcome 3: Co-design and implement observation strategies. In: *Ocean Acidification Research for Sustainability - A Community Vision for the Ocean Decade*. IOC-UNESCO. (IOC Technical Series, 185.) Paris, UNESCO. (pp 27-37).

Almendra I., B. Dewitte, V. Garçon, P. Muñoz, C. Parada, I. Montes, O. Duteil, A. Paulmier, O. Pizarro, M. Ramos, W. Koeve and A. Oschlies, 2024: Emergent constraint on oxygenation of the upper South Eastern Pacific Oxygen Minimum Zone in the twenty-first century, Communications Earth & Environment, in press.

Core theme 1:

Resplandy, L., Hogikyan, A., Müller, J. D., Najjar, R. G., Bange, H. W., Bianchi, D., et al. (2024). A synthesis of global coastal ocean greenhouse gas fluxes. Global Biogeochemical Cycles, 38, e2023GB007803. https://doi.org/10.1029/2023GB007803

Core theme 3:
Violaki et al. (2024). Chemosphere 348, 140746, DOI:10.1016/j.chemosphere.2023.140746

Demasy C. (2023). Solubility and bioavailability of Patagonian dust in the future Southern Ocean. Doctoral thesis, Université Paris Cité. https://theses.fr/s230653
Demasy C., Boye M., Lai B., Burckel P., Feng Y., Losno R., Borensztajn S., Besson P: Iron dissolution from Patagonian dust in the Southern Ocean: under present and future conditions. Frontiers in Marine Science, in press.

Parouffe A., Garçon V., Dewitte B., Paulmier A., Montes I., Parada C., Mecho A. and Veliz D., 2023, Evaluating future climate change exposure of marine habitat in the South East Pacific based on metabolic constraints. *Front. Mar. Sci*. 9:1055875. doi: 10.3389/fmars.2022.1055875

Core theme 4:
Sellegri, K., T. Barthelmeß, J. Trueblood, A. Cristi, E. Freney, C. Rose, N. Barr, M. Harvey, K. Safi, S. Deppeler, K. Thompson, W. Dillon, A. Engel, and C. Law, Quantified effect of seawater biogeochemistry on the temperature dependence of sea spray aerosol fluxes Atmos. Chem. Phys., https://doi.org/10.5194/acp-2022-790, 2023

Core theme 5:
Chamba G., M. Rissanen, T. Barthelmeß, C. Rose, S. Iyer, A. Saint-Macary, A. Saiz-Lopez, M. Rocco, K. Safi, S. Deppeler, N. Barr, M. Harvey, A. Engel, E. Dunne, C.S. Law and K. Sellegri, Nitrate-based nighttime atmospheric nucleation driven by marine microorganisms, PNAS, 120 (48), https://doi.org/10.1073/pnas.2308696120, 2023.

Peltola, M., Rose, C., Trueblood, J. V., Gray, S., Harvey, M., and Sellegri, K.: Chemical precursors of new particle formation in coastal New Zealand, Atmos. Chem. Phys., 23, 3955–3983, https://doi.org/10.5194/acp-23-3955-2023, 2023.

Berthet, S., Jouanno, J., Séférian, R., Gehlen, M., and Llovel, W.: How does the phytoplankton–light feedback affect the marine N_2O inventory?, Earth Syst. Dynam., 14, 399–412, https://doi.org/10.5194/esd-14-399-2023, 2023.

Cross-Cutting Theme: polar oceans and sea ice
Smith, M. M., Angot, H., Chamberlain, E. J., Droste, E. S., Karam, S., Muilwijk, M., Webb, A. L., Archer, S. D., Beck, I., Blomquist, B. W., Bowman, J., Boyer, M., Bozzato, D., Chierici, M., Creamean, J., D'Angelo, A., Delille, B., Fer, I., Fong, A. A., Fransson, A., Fuchs, N., Gardner, J., Granskog, M. A., Hoppe, C. J. M., Hoppema, M., Hoppmann, M., Mock, T., Muller, S., Müller, O., Nicolaus, M., Nomura, D., Petäjä, T., Salganik, E., Schmale, J., Schmidt, K., Schulz, K. M., Shupe, M. D., Stefels, J., Thielke, L., Tippenhauer, S., Ulfsbo, A., van Leeuwe, M., Webster, M., Yoshimura, M., and Zhan, L.: Thin and transient meltwater layers and false bottoms in the Arctic sea ice pack-Recent insights on these historically overlooked features, Elem. Sci. Anthr., 11, 00025, https://doi.org/10.1525/elementa.2023.00025, 2023.

Yue, F., Angot, H., Blomquist, B., Schmale, J., Hoppe, C. J. M., Lei, R., Shupe, M. D., Zhan, L., Ren, J., Liu, H., Beck, I., Howard, D., Jokinen, T., Laurila, T., Quéléver, L., Boyer, M., Petäjä, T., Archer, S., Bariteau, L., Helmig, D., Hueber, J., Jacobi, H.-W., Posman, K., and Xie, Z.: The Marginal Ice Zone as a dominant source region of atmospheric mercury during central Arctic summertime, Nat. Commun., 14, 1-13, https://doi.org/10.1038/s41467-023-40660-9, 2023.

Willis, M.D. et al.: Polar oceans and sea ice in a changing climate, *Science of the Anthropocene* 11 (1): 00056, 2023. doi.org/10.1525/elementa.2023.00056

Mallet M.D. et al.: Untangling the influence of Antarctic and Southern Ocean life on clouds, *Science of the Anthropocene* 11 (1): 00130, 2023. doi.org/10.1525/elementa.2022.00130

Lapere R. et al.: The Representation of Sea Salt Aerosols and Their Role in Polar Climate Within CMIP6, JGR Atmospheres, 2023. doi.org/10.1029/2022JD038235

Lapere R. et al.: Polar Aerosol Atmospheric Rivers: Detection, Characteristics, and Potential Applications, Journal of Geophysical Research: Atmospheres, 129, 2, 2024. doi.org/10.1029/2023JD039606

Shaddy, A., Thomas, J.L., et al.: Modelling the coupled mercury-halogen-ozone cycle in the central Arctic during spring, *Science of the Anthropocene*, 11 (1): 00129, 2023. doi.org/10.1525/elementa.2022.00129

Cross-Cutting Theme: Science and society

Capson, T.L. and M. Boye: Climate change: West Africa's oceans at risk because of a lack of monitoring. The conversation, published November 9th, 2022. https://theconversation.com/climate-change-west-africas-oceans-at-risk-because-of-a-lack-of-monitoring-192274

Capson, T.L., Boye, M., Machu, E, Schmidt, J.O., Thomas, Y., Capet, X., Diouf, M.: Expanding ocean observation and climate services to build resilience in West African fisheries. One Earth, 4, 1062-1065, 2021, https://doi.org/10.1016/j.oneear.2021.07.010

Cross-Cutting Theme: upwelling systems

Zouhair. L., Cornejo-D'Ottone M., Singh A., Aristegui J., Dewitte, B., Fawcett S., Garçon V., Lovecchio E., Molina V., and Vinayachandran P.N.M., 2024. Biogeochemistry of greenhouse gases in coastal upwelling systems: processes and sensitivity to global change, *Elementa: Science of the Anthropocene, Elementa: Science of the Anthropocene,* 12 (1): 00088, https://doi.org/10.1525/elementa.2023.00088

4. Did you engage any stakeholders/societal partners/external research users in order to co-produce knowledge in 2023? If yes, who? How did you engage?

PART 2 - Planned activities for 2024 and 2025

1. Planned major national and international field studies and collaborative laboratory and modelling studies (incl. all information possible, dates, locations, teams, work, etc.).

SOPHYAC-Light

Ship campaign on board the *Marion Dufresne* during Jan-Feb 2025 to the Terres Australes et Antarctiques Francaises (TAAF) from La Réunion. The main objective is to investigate the impact of UV light on marine microorganisms of the Southern Ocean and the subsequent release of precursor gases to nucleation in the atmosphere.

Contact: karine.sellegri@uca.fr and boye@ipgp.fr

Model intercomparison between LAMTOS and IGE, which is a CATCH (IGAC and SOLAS) effort: *https://github.com/jenniethomas/arctic-bromine-model-intercomp*

Contact: jennie.thomas@univ-grenoble-alpes.fr

Amsterdam Island: Installation of a new station for aerosol measurements

Researcher from LaMP and IGE will initiate aerosol measurements (number size distribution 2 nm-10 microns; submicron aerosol chemical composition, fluorescence, scattering properties) at Amsterdam Island. Installation planned April 2024.

Contact: karine.sellegri@uca.fr and aurelien.dommergue@univ-grenoble-alpes.fr

MAP-IO

The *R/V Marion Dufresne* has been equipped with atmospheric and oceanic sensors that operate on a continuous basis since 2022, and will continue to be tested as a mobile measurement station for 2024. Atmospheric sensors relevant for SOLAS comprise SMPS, CPC, CCNC, OPC, ozone and NOx analysers, picaro for GHG, sunphotometer and miniSAOZ, while oceanic sensors comprise an on-line flow cytometer.

Contact: pierre.tulet@aero.obs-mip.fr

REFUGE-ARCTIC campaign aboard the Amundsen this summer (early August to early October 2024). The objective is to study the Nares Strait and the Lincoln Sea. The campaign is organized by Mr. Ardyna from Takuvik. Hélène Angot will have an atmospheric mercury instrument on board and Lars-Eric Heimburger-Boavida is in charge of Hg measurements in the water column. They will try to calculate exchange flows at the ocean-sea ice-atmosphere interface in different types of ice (multi-year or first-year sea ice) from these measurements.

Contact: helene.angot@univ-grenoble-alpes.fr and lars-eric.heimburger@mio.osupytheas.fr

CaledoNia

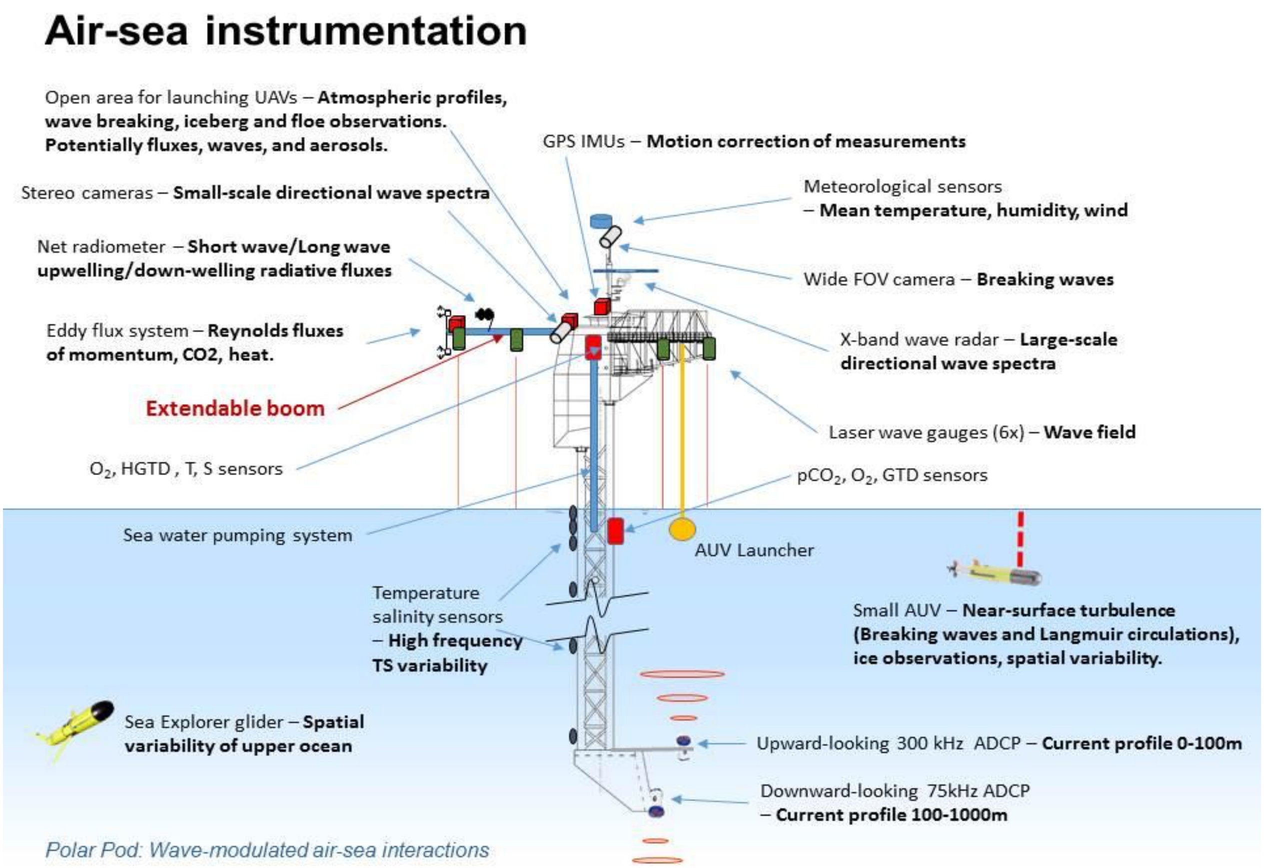
A field campaign on land and at sea will be carried out by an IPGP team in collaboration with IRD at Nouméa in June-July 2024 to study the island mass effect of New Caledonia on marine biogeochemistry and phytoplankton assemblages.

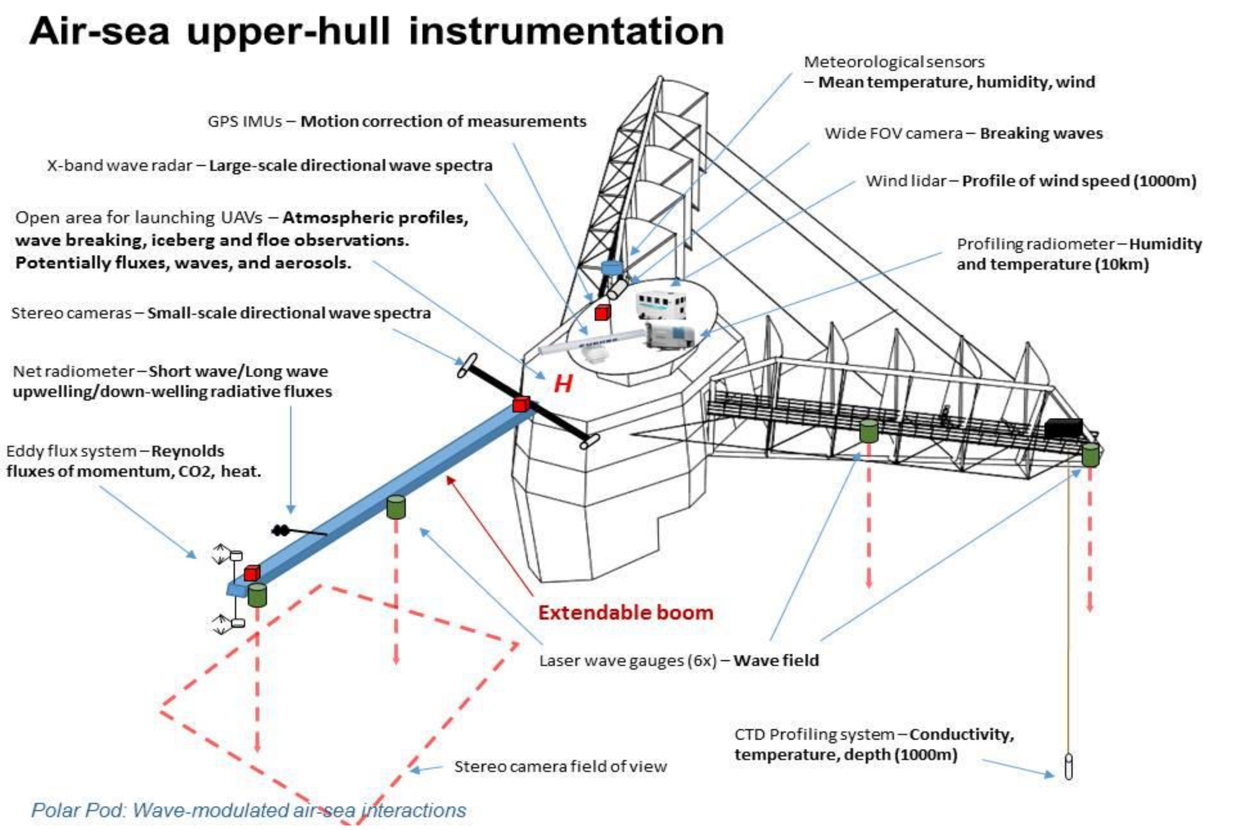
Contact: boye@ipgp.fr

Polar POD program

The Polar POD program really starts after more than a decade of preparation (https://www.polarpod.fr/). The "Plateforme Océanique Dérivante Polaire", known as the "Polar POD", has been primarily conceived to support an exploration of the Southern Ocean, with the explorer mindset of Jean-Louis Etienne, who is known for having dedicated his life to exploration of our planet. The expedition goal is to undertake two circumnavigations of the Southern Ocean, wandering in the turbulent waters of the Antarctic Circumpolar Current, one of the main physical features of this ocean of global importance that also drives ecosystem dynamics in the sub-Antarctic domain. The Southern Ocean is the only ocean whose waters circulate around the globe without meeting continental masses, generating specific large-scale physical and biological processes. Known as a major sink for atmospheric CO_2, its water masses also play an important role in biogeochemical cycles and in the regulation of the Earth's climate. This region is also home of extreme meteorological conditions, with strong winds and waves. Only very few people are living in the area but anthropogenic perturbation is present and imported here from long range transport. The Polar POD will provide an unprecedented means of collecting continuously and simultaneously a wide range of physical, biogeochemical, and biological observations of the upper layers of the ocean and of the overlying atmosphere that will allow us to answer these climatically related important questions in the current global change context.
More than 100 researchers of 43 research institutions are involved in the Polar POD scientific program. It will be an essential contribution to the program of the United Nations Decade of Ocean Science for Sustainable Development (2021-2030). All data will be available to the entire scientific community as well as the general public.

Contacts: David Antoine (david.antoine@curtin.edu.au), Peter Sutherland (peter.sutherland@ifremer.fr), Karine Leblanc (karine.leblanc@mio.osupytheas.fr), Cédric Cotte (cedric.cotte@locean.ipsl.fr), Rémi Losno (losno@ipgp.fr)





The Polar POD project includes five major components: Ocean-Atmosphere exchanges of momentum, energy and mass, Bio-optics, ocean colour and phytoplankton, permanent residents (biodiversity), anthropogenic influence and impacts, passive and active acoustics.

2. Events like conferences, workshops, meetings, summer schools, capacity building etc. (incl. all information possible).

A **SOLAS-France workshop** will be organized at IPGP (Paris) in spring/summer 2024.

A **new SOLAS-France website** hosted at IPGP will be lunched.

3. Funded national and international projects/activities underway.

PYROPLANKTON-LEFE: PIs C. Guieu, LOV et E. Ortega-Retuerta LOMIC, funded by LEFE of French CNRS-INSU, 2023-2024.

SOPHYAC-Light: PI K. Sellegri, funded by LEFE of French CNRS-INSU, 2024-2025.

CaledoNia: PI M. Boye, funded by LEFE-EC2CO of French CNRS-INSU, 2024-2025.

4. Plans / ideas for future national or international projects, programmes, proposals, etc. (please indicate the funding agencies and potential submission dates).

OABI-one: Merging new emission schemes with new ocean satellite products in mesoscale transport models, evaluated using in situ and remote sensing satellite products. To be submitted to the French spatial agency CNES in September 2024. Collaboration LaMP-LOA-LAERO-LOV-MIO

5. Engagements with other international projects, organisations, programmes, etc.

SCOR 166 - DMS-PRO (2023-2027): Developing resources for the study of Methylated Sulfur compound cycling PROcesses in the ocean (https://scor-int.org/group/developing-resources-for-the-study-of-methylated-sulfur-compound-cycling-processes-in-the-ocean-dms-pro/).
Contact: Eva.Bucciarelli@univ-brest.fr

United Nations Decade of Ocean Science for Sustainable Development (https://oceandecade.org/)

IOCCP (International Ocean Carbon Cooperation Program, https://www.ioccp.org/)

GOOD (Global Ocean Oxygen Decade, https://www.ioc.unesco.org/en/global-ocean-oxygen-decade)

GOOS (Global Ocean Observing System, https://goosocean.org/)

BioGeoSCAPES (Ocean metabolism and nutrient cycles on a changing planet, https://biogeoscapes.org/)

Futurearth (https://futureearth.org/)

Comments